Video-assisted replacement or bypass grafting of the descending thoracic aorta with a new sutureless vascular prosthesis: An experimental study

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Purpose: **The feasibility of the video-assisted insertion of a new sutureless vascular prosthesis was studied.**

Methods: **Seven sheep, weighing 25 to 35 kg, were operated on under general anesthesia. The animals were intubated with a single-lumen endotracheal tube and placed in the right lateral decubitus position. A thoracoscope was introduced in the 11th intercostal space, and a minithoracotomy (4 to 5 cm) was performed in the seventh intercostal space. After retraction of the lung, a short segment (10 cm) of the descending thoracic aorta was exposed. Our prosthesis was made of Dacron and was specifically designed to be inserted without a suture. After systemic heparinization, the aorta was cross-clamped with two vascular clamps introduced into the thoracic cavity through two 5-mm thoracic incisions. The aorta was either replaced (five cases) or bypass grafted (two cases). At the completion of the procedure, blood pressure was pharmacologically increased (5 mg intravenous bolus of epinephrine), and each anastomosis was checked for bleeding. All animals were killed, and the prosthesis was retrieved for macroscopic examination.**

Results: **The procedure was completed in each case without extension of the minithoracotomy. Insertion of the prosthesis was easy and fast, and completion of each anastomosis required 10 to 15 minutes. A 3- to 4-mm space between each clip was sufficient for proper attachment. All procedures were performed in less than 120 minutes. No bleeding was observed at the level of each anastomosis, even when a sustained high blood pressure was induced. The proper insertion of the prosthesis and the absence of any anastomotic stenosis was confirmed by means of macroscopic examination.**

Conclusion: **Video-thoracoscopic replacement or bypass grafting of the descending thoracic aorta was easy with this new sutureless vascular prosthesis. Minimally invasive vascular surgery might be facilitated with such a prosthesis. However, long-term animal studies are required before human implantation can be undertaken. (J Vasc Surg 1999;30:320-4.)**

There has been a great interest in minimally invasive vascular surgery since the first report of it by Dion et al.[1] Several experimental and clinical studies have been reported subsequently.[2-11] For most authors, a major (if not the greatest) difficulty encountered during video-assisted aortic surgery is performing a conventional vascular anastomosis.

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The widespread and rapid development of the laparoscopic approach will be expected if an efficient, sure, and fast anastomotic procedure becomes available. Sutureless vascular anastomoses have been performed since the beginning of this century.[12] Different sutureless vascular prostheses have been investigated in clinical or experimental studies,[13] but their use in clinical practice remains limited and controversial.[14,15]

We studied the video-assisted replacement or bypass grafting of the descending thoracic aorta with a new vascular prosthesis, specifically designed for sutureless vascular anastomosis.

METHODS

Seven sheep, weighing 25 to 35 kg, were used, with the approval of the Animal Research Committee. All animals received humane care, as dictated by the

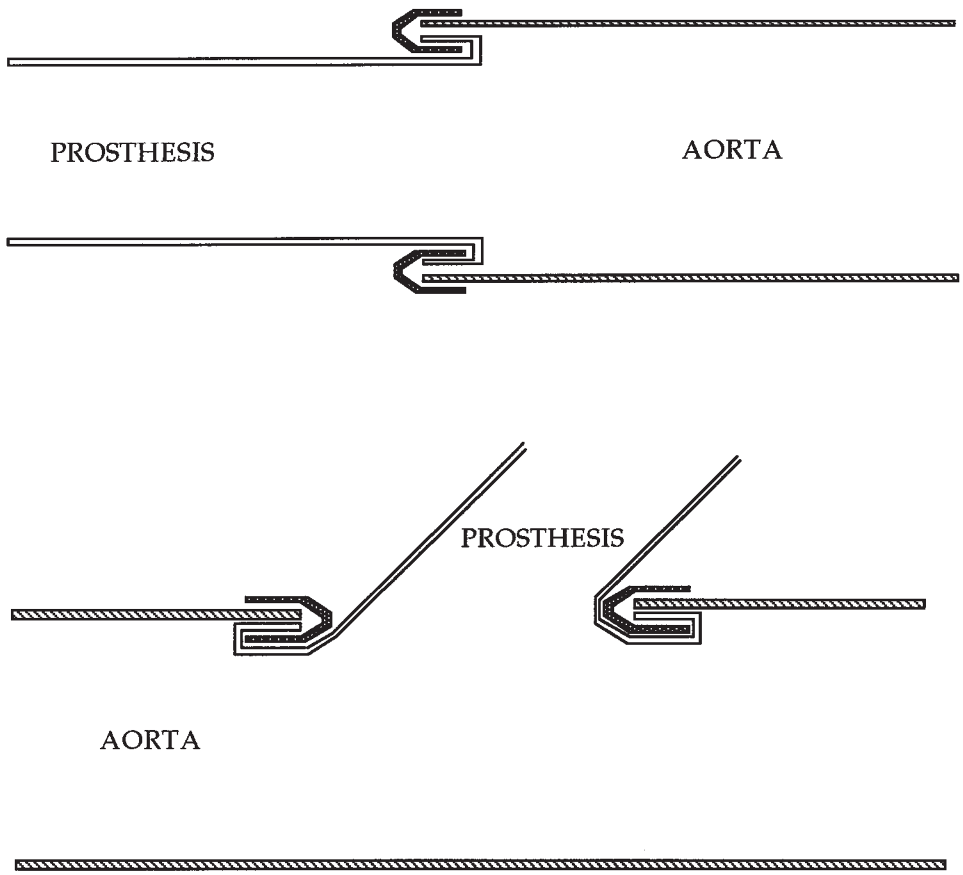

Fig 1. Schematic representation of the cuffed prosthesis, which is designed for either end-to-end (**top**) or end-to-side anastomoses (**bottom**). The cuff is attached circumferentially to the vascular wall by means of several clips, which are never in contact with the blood flow.

principles of laboratory care formulated by the National Academy of Science and published by NIH (publication 86-23, 1985).

General anesthesia was induced with intravenous propofol (8 mg/kg) and maintained with isoflurane gas administered through a single-lumen endotracheal tube. Continuous blood pressure and electrocardiogram monitoring was performed during the experiment.

All animals were placed in right lateral decubitus position. A 1.5-cm skin incision was performed in the 11th intercostal space in the posterior axillary line. An 11-mm thoracoport was then inserted, and a 30-degree thoracoscope was introduced into the thoracic cavity through this port. After inspection of the pleural space, a 4- to 5-cm minithoracotomy was performed in the seventh interspace with visual control. A rib retractor was used, and all the subsequent procedures were performed with conventional instruments.

Exposure of the descending thoracic aorta was facilitated by division of the inferior pulmonary ligament and retraction of the lung. The posterior mediastinal pleura was opened along the aorta, and a short aortic segment (10 cm) was dissected free. An umbilical tape was placed around the aorta, thus facilitating the dissection and clipping of the intercostal arteries. After systemic heparinization (150 IU/kg), two straight vascular clamps were introduced into the thoracic cavity through two 5-mm thoracic incisions. Both end-to-end and end-to-side anastomoses were done in this experiment. Because of the small diameter of the sheep aorta (10 to 12 mm), total cross-clamping was also used to complete each end-to-side anastomosis.

Aortic replacement. We used 10-mm Dacron prostheses (Perouse Implant, Bornel, France) with cuffed extremities. Each cuff was made of Dacron and was 6-mm wide (Fig 1). After cross-clamping the aorta, a short aortic segment (5 to 8 cm) was resected. One extremity of the prosthesis was then

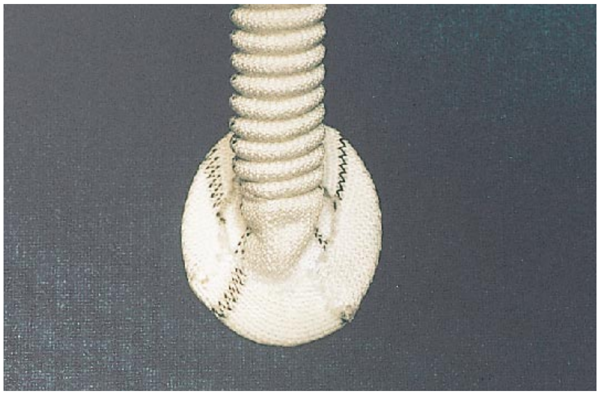

Fig 2. Upper view of a cuffed extremity of a new sutureless vascular prosthesis designed for end-to-side anastomosis.

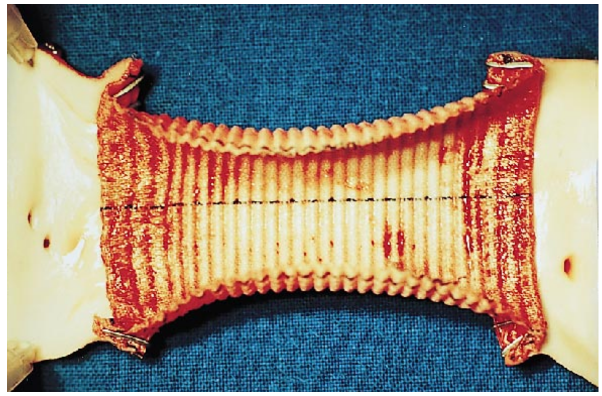

Fig 4. Postmortem luminal view of the cuffed prosthesis after a video-assisted aortic replacement.

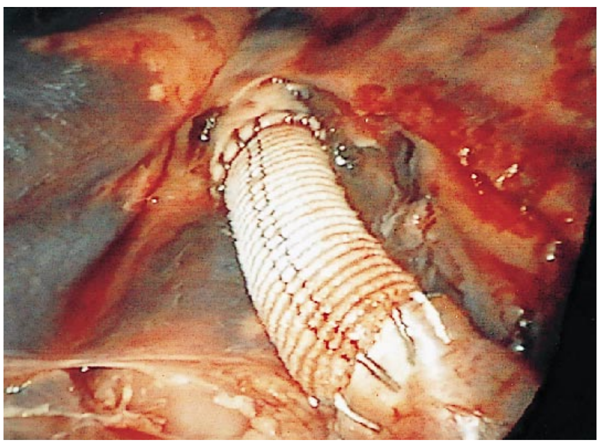

Fig 3. Perioperative view after completion of a video-assisted aortic replacement with a cuffed prosthesis.

introduced into the proximal vascular stump. Once properly placed, the cuff was attached circumferentially to the arterial wall with vascular clips (Horizon, Peters, Bobigny, France). These clips were made of titanium and were 0.5 mm wide and 5.5 mm long in the closed position.

After completion, the proximal anastomosis was checked for bleeding by releasing the proximal vascular clamp. The distal anastomosis was performed in the same manner.

Aortoaortic bypass grafting. We used an 8-mm diameter Dacron prosthesis (Perouse Implant, Bornel, France) with a 6-mm wide cuff at both extremities (Figs 1 and 2). After cross-clamping the aorta, a longitudinal arteriotomy was performed with an 11-mm blade. A cuffed extremity was then introduced into the vascular lumen and attached to the vascular wall with titanium clips, beginning on the midportion of its medial and lateral sides. After completion, the proximal anastomosis was checked for bleeding by releasing the proximal vascular clamp. The distal anastomosis was performed the same way.

Before the animals were killed, their blood pressure was increased by means of intravenous injection of epinephrine (5 mg). The animals were killed with standard euthanasia solutions. The vascular graft, including both anastomoses, was excised and checked for any macroscopic technical defect.

RESULTS

All operations were completed without an extension of the minithoracotomy. Aortic replacement was performed in five cases, whereas an aortoaortic bypass grafting procedure was performed in two additional animals.

Insertion of the sutureless prosthesis was easy and fast. A 3- to 4-mm space between each clip was sufficient for proper attachment of the vascular prosthesis (Fig 3). Cross-clamping times ranged from 15 to 20 minutes for completion of each anastomosis. Duration of the intervention was less than 120 minutes in each case (98 ± 5 [SE]; range, 80 to 120 minutes).

Five milligrams of epinephrine increased systolic blood pressure from 92 ± 4 mm Hg to 213 ± 11 mm Hg and diastolic blood pressure from 49 ± 3 mm Hg to 161 ± 6 mm Hg. Blood loss was minimal during the surgical procedures. No bleeding was observed at the level of the anastomoses when a sustained (more than 5 minutes) and high blood pressure was induced after intravenous epinephrine administration.

Proper fixation of the sutureless vascular graft and no anastomotic stenosis was shown by means of the postmortem macroscopic examination (Fig 4).

Table I. Cross-clamp times in video-assisted aortic surgery

Authors (year)	*Population*	*Surgical procedure*	*Mini-incision?*	*Aortic clamp time (minutes)*
Said (1996)[6]	Pig (n = 9)	AF	No	(30 to 90)
Ahn (1997)[7]	Human (n = 1)	ABF	No	210
Barbera (1998)[9]	Human (n = 13)	AF (n = 5)	No	66 ± 4 (55 to 75)
		ABF (n = 8)		68 ± 9 (55 to 120)
Hill (1998)[10]	Dog (n = 5)	ABF	No	95 (74 to 115)
Byrne (1996)[4]	Dog (n = 10)	ABF	No	87 ± 9
			Yes (5 cm)	51 ± 8
Berens (1995)[2]	Human (n = 1)	ABF	Yes (4 cm)	53
Jones (1996)[3]	Pig (n = 10)	AF	Yes (4 cm)	27.5 ± 5
Chen (1996)[5]	Human (n = 9)	AR	Yes (8 to 11 cm)	54 ± 6 (32 to 93)

AF, Aortofemoral bypass grafting; *ABF,* aortobifemoral bypass grafting; *AR,* aortic replacement.
Results are expressed as mean ± SEM, when possible; ranges are within brackets.

DISCUSSION

In 1993, Dion et al[1] reported a laparoscopy-assisted aortobifemoral bypass grafting procedure in a patient who had aortoiliac occlusive disease. After dissection of the aorta with laparoscopy, a minilaparotomy was performed to complete an end graft-to-side aorta anastomosis. Since this first report, several experimental and clinical experiments in minimally invasive vascular surgery have been published. Through a laparoscopy-assisted approach, Chen et al[5] performed an abdominal aortic reconstruction for aneurysmal disease. Hill et al[10] described the completion of an aortobifemoral bypass grafting procedure in a canine model, with the proximal anastomosis performed thoracoscopically on the distal descending thoracic aorta. To date, we are unaware of any video-assisted aortic replacement of the descending thoracic aorta.

Whatever surgical approaches (transperitoneal or retroperitoneal) or strategies (with or without the use of a pneumoperitoneum and/or a minilaparotomy) were used, a major difficulty encountered by most authors was performing a vascular anastomosis during minimally invasive surgery. Reported aortic cross-clamp times ranged approximately from 20 to 210 minutes, with the shortest time being achieved when a mini-incision was done (Table I). One can easily imagine that calcification of the vascular wall may prolong the suturing or even necessitate a conversion to an open technique. Alternatives to conventional anastomosis may make minimally invasive surgery easier and faster.

A few methods of sutureless anastomosis of a prosthesis on large diameter vessels are available. Ringed prostheses usually allow a fast insertion.[14] However, their use has been associated with several complications, such as slippage, intimal tearing, and obstruction of major collateral vessels. To date, their clinical experience has been limited and has remained controversial.[15] Stapling of a vascular prosthesis has already been performed with good anatomical results in animals.[16-17] However, stapling of a vascular prosthesis may be difficult and even risky in the case of (calcified) atheromatous vessels. To the best of our knowledge, no such insertion has been described in humans.

The "cuffed" prosthesis we used in this study was specifically designed to perform a vascular anastomosis that would be simple, fast, and efficient during minimally invasive vascular surgery. We chose to perform a video-assisted thoracoscopic replacement and bypass grafting procedure of the descending thoracic aorta in the sheep model. In contrast to exposing the infrarenal abdominal aorta, exposure of the descending thoracic aorta was easy. We did not use a double-lumen endotracheal tube, lung exclusion, or insufflation of carbon dioxide. Division of the inferior pulmonary ligament and retraction of the lung was always sufficient for good exposure. Under these conditions, end-to-end and end-to-side anastomoses of the cuffed prosthesis remained simple and fast. Each anastomosis was completed in 10 to 15 minutes, which favorably compares with any experience in video-assisted aortic surgery reported thus far in the literature (Table I). Furthermore, because fixation of the graft does not require any puncture of the vascular wall, we believe that its use will remain possible in the case of aortic calcification. We are currently investigating in our laboratory a device that will allow a faster completion of a vascular anastomosis, probably less than 1 minute.

Using clips to perform a sutureless vascular anastomosis has several advantages. Vascular clips are widely distributed and easy to apply, and, when required, they are easy to remove and well tolerated. In our daily activity, these clips are used for occlusion of collaterals of venous and arterial grafts in coronary artery surgery. We are not aware of any bleeding related to short- or long-term deterioration of the material. Therefore, we believe that using clips for sutureless vascular anastomosis would not be associated with a higher risk of postoperative bleeding in the long run, but this should first be evaluated in animal studies.

We used a video-assisted surgical approach rather than a totally thoracoscopic procedure for several reasons:

- The use of conventional instruments (including the clip applicator) was possible.
- Exposure of the aorta was particularly fast and sure (when necessary, emergent standard thoracotomy would probably be performed faster).
- A thoracoscopic procedure would have necessitated more thoracic incisions (seven skin incisions were performed in the study of Hill and colleagues[10]). We made four thoracic incisions, but with the new vascular clamps, two incisions would be sufficient.
- To our knowledge, there is no study that compares the effect of a video-assisted or a totally thoracoscopic procedure on postoperative pain (and other complications).

We think that our model is appropriate to evaluate any type of anastomosis on large vessels with minimally invasive surgery. However, for long-term studies, some modifications should be added to prevent postoperative paraplegia. Indeed, in our experience, a 15-minute cross-clamping of the descending thoracic aorta is associated with a 50% risk of paraplegia. A possible solution to prevent this complication when operating with thoracoscopy would be the use of an active shunt between a carotid and a femoral artery.

In conclusion, we have shown that video-assisted replacement or bypass grafting of the descending thoracic aorta was feasible in sheep with a new sutureless vascular prosthesis. Some refinements and long-term animal studies are warranted before human implantation is undertaken.

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